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Fernando Machado de Mello, Essaïd Bilal

AGES CONSTRAINTS IN PEGMATITE PROVINCE RELATED TO CHARNOCKITIC HOST ROCKS IN MINAS GERAIS, BRAZIL

Fernando Machado de MELLO[1], Essaid BILAL[2*],

1- Universidade Federal Rural do Rio de Janeiro, Brazil (UFRRJ) - fermamll@ufrrj.br
2- École des Mines de Saint-Etienne, Dept. de Géosciences & Environnement-158, cours Fauriel 42023 Saint-Etienne cedex 2, France; *bilalessaid@gmail.com*; Tel/Fax – +33 4 77 42 01 63/ +33 4 7749 9707

Abstract Cambrian-Neoproterozoic granitoids suites in southeastern Brazil are the main host rocks of largest pegmatite field of Brazil, the Eastern Pegmatite Province. The P-Li-Nb pegmatites group represent the richest in precious stones like Beryl, Aquamarine, Topaz and Tourmaline. Two types of pegmatites are characterized by their mineralogical characteristics and tectonic and magmatic relations. The first group formed during compressive event about 582 Ma and the second pegmatite group was formed by cooling of residual melts during the transition to an extensional phase (520-500Ma) of the Brasiliano/Pan-African Orogeny, related to metamorphic rock melts (gneiss migmatite, gneiss) and extensive granite-charnockite emplacement. The new charnokite isotopic data presented here constrain the latest pegmatite genesis at about 500 Ma as its maximum age.

Keywords: Geochronology Pegmatite Charnockite; Brasiliano/Pan-African; Magmatic and Tectonic Relationships; Minas Gerais-Brazil.

1. Introduction

The Neoproterozoic evolution of Northern Mantiqueira Province, Brazil, was characterized by an intense granitic magmatism, associated with a network of continental-scale ductile shear zones, related to a compressive, transpressional and later extensional tectonics. The arc-type structure, which develops over more than 47,500 km^2 in southeast Brazil, links many lithospheric tectonic discontinuities to an abundant and various magmatism. This paper is mainly concerned with geochronological and tectono-magmatic relationships of the Pegmatite Province and the latests magmatic events in that region (Fig. 1). There, the plutonic framework intruded in the Archaean and Paleoproterozoic magmatic and metamorphic basement, has been emplaced during different periods in relation to the geotectonic events and includes important pegmatite fields.

2. Regional setting

The Rio Doce region is located in the northern portion of the Mantiqueira Structural Province (Almeida and Hasuy, 1980), east of São Francisco Craton in the eastern Minas Gerais and northwestern Espirito Santo states. This province is represented by Neoproterozoic mobile belts that surrounded the São Francisco cratonic block and is associated to the Brasiliano/Pan-African Orogeny (600 - 450 Ma). These mobile belts reworked the Archaean-Palaeoproterozoic country rocks (high and low-grade metamorphic rocks of Piedade, Paraíba do Sul and Pocrane Complexes; Juiz de Fora and Neoproterozoic supracrustal sequences of Rio Doce Group) and enabled the intrusion of granitoid plutons and pegmatites. Several rare metals and gem mineral rich pegmatites are related to charnockitic rocks (hypersthene-granitoids).

Petrographic, geochemical and structural features allow the separation of these rocks into pre-, syn-, late and post-tectonic granitoids. The whole emplacement process lasted less than 100 Ma: from 595 Ma for the pre-tectonic granitoids, to 500 Ma for the post-tectonic ones. During this interval, a 45 Ma magmatic quiet period (from 582 to 537 Ma) can also be identified. Detailed field observations and mapping, coupled with petrological and geochemical observations, indicate an important role of the Archaean and Paleoproterozoic crust in the genesis of these granitoids, showing even evidence of some mantle interactions.

3. Pegmatite groups

According to Bilal et al, 2000 there are two main pegmatite groups; the first one is considered the result of fractional crystallization of a syntectonic magmas. Its representative types are leucogranites and P-Li-Be bearing pegmatites. The isotopic ages of these intrusions are estimated at about 582 Ma. Their presence is mainly confined to the area near the cities of Governador Valadares, Teofilo Otoni, Araçuaí, Conselheiro Pena and São José da Safira.

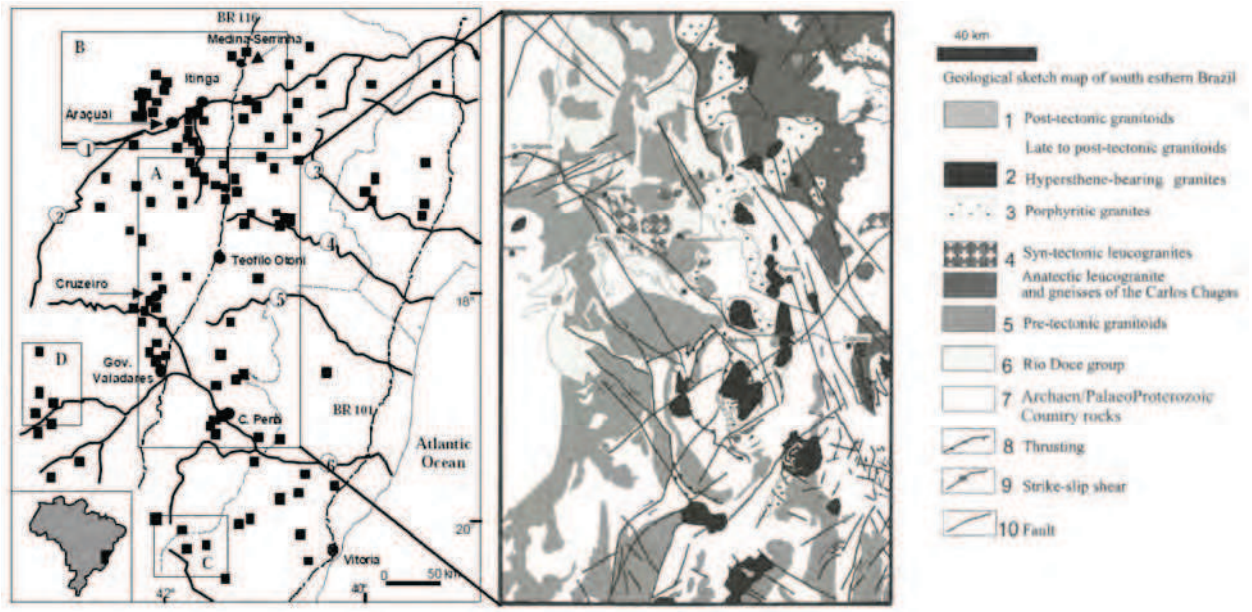

Fig. 1. Distribution fields of pegmatites in southeastern Brazil. Pegmatites from the first group occur in the quadrangles A (Gov.Valadares, Teófilo Otoni, São José da Safira and Galiléia) and B (Araçuai and Itinga). Pegmatites from second group are in quadrangles C (Caparaó, Espera Feliz) and D (Sta Maria de Itabira). Dots: Federal State Boundaries. Roman Numerals: Federal States (I- Bahia; II- Espírito Santo; III- Minas Gerais). Open circles with Arabic numerals: Rivers 1- Jequitinhonha; 2- Araçuai; 3- Itanhém; 4 Mucuri; 5- São Mateus; 6 Rio Doce. BR 116 and 101: Federal Highways. Blacksquares: pegmatites. Black circles: towns. (Pinto C. P. 1997, Bilal E. et al. 1998, 2000a, 2000b, 2001, Mello F.M. and Bilal E., 2004)

The second group was formed during the second phase D2 (520-500Ma) of the Brasiliano metamorphic rock fusion The main pegmatite bodies show outcropping lengths ranging from 150 m up to 1300 m and widths ranging from 10m up to 60 m. They are subvertical bodies striking N10-20°W. The pegmatite outcrops at different topographic levels, ranging from 150 m up to 1100 m into staurolite-garnet schists and paragneisses, concordant and discordant to the Brasiliano structures.

Their internal features are in all of them essentially very similar. They show consistent mineral assemblages arising from an internal zoning around the quartz core. The centimetric tourmaline crystals have been collected from the border and the wall zones (black tourmalines), from the intermediate zones (black, green, blue and pink tourmalines) or even from metasomatic pockets (green, blue and pink to red tourmalines). The schorlitic tourmalines are associated with quartz, muscovite, (K,Na)-feldspar, garnet (almandine-spessartite), columbite-tantalite (Nb>Ta) and prismatic beryl. The elbaitic ones are found together with Na-feldspar (cleavelandite), quartz, amblygonite, spodumene, Li-rich violet micas, morganite, tantalite-columbite (Ta>Nb) and spessartite garnet.

We study many little leucogranite bodies linked to the pegmatites. They are controlled by a previous main compressive deformation phase Dl. Ten individual zircon crystals within leucogranites are dating 579 ± 5 Ma. The very Sr-enriched and Nd-depleted initial ratios ($0.782 \leq {}^{87}Sr/{}^{86}Sr_{(i)} \leq 0.823$ and $-8.2 \leq \varepsilon Nd_{(600)} \leq -7.4$) must be related to an important role of a crustal source. They are linked with Urucum granite (584 ± 2 Ma zircon U-Pb) suite in Galilea region (Nalini et al., 2000). The syn-tectonic magmatic series are related to crustal melting produced by decompression and thermal relaxation (550-700°C and 4-5 kbar). These perphosphorous leucogranites displays porphyritic textures and are characterized by the presence of apatite phenocrystals (2 cm) and P-rich feldspars. They are highly peraluminous ($1.07<ASI<1.38$) and, vary from the porphyritic granites to the haplopegmatitic facies. Their P_2O_5 contents (0.28 to 1.06 wt%) decrease with increasing SiO_2 (72-75 wt%) can be classified as phosphorus-rich leucogranites. Very high concentrations of P_2O_5 in silicic peraluminous granites are symptomatic of strong differentiation. The MgO/TiO_2 ratio nears 3, which may be compared to the typical granites of crustal origin. In a same way, a decrease of major elements (CaO, Fe_2O_3, MgO, TiO_2) and of trace elements (Zn, V, Sc, Co, Cr, Ni, REE) are observed from the porphyritic granites to the haplopegmatites.

The Galileia suite, with 594 ± 6 Ma zircon U-Pb ages, is related to few pegmatite bodies and is characterized by elongated batholiths trending in the NW-SE and N-S directions associated with high angle shear zone. The batholiths present solid state and magmatic flow foliations and a well-developed

magmatic lineation. Two deformation phases were described: the first was responsible for the development of a solid-state foliation and magmatic flow lineation in the granitic suites and a schistosity and stretching lineation in the country rocks of the São Tomé schist, which hosts, in its foliation planes important pegmatite bodies. The second was responsible for an extensional crenulation cleavage and other associated structures.

4. Charnockites

The charnockites related to pegmatite bodies discussed here belong to a group mainly consisted of balloon-shaped, bimodal, granitic and/or charnockitic to dioritic/noritic intrusions, formed and emplaced in the deep crust (> 25 km). Geochemically, they are high-K and high-Fe calc-alkaline to alkaline with widespread evidence of magma mixing and mingling processes. These bodies are supposed to be the source of residual pegmatites that can host deposits of aquamarine, topaz and quartz crystals. These pegmatites are generally rich in biotite and poor in tourmaline. Lithium minerals are rare or absent. These pegmatites are the source of blue and greenish blue aquamarine, colourless topaz and quartz.

4.1 Charnockites Rb/Sr, U/Th/Pb, U/Pb and Sm/Nd Isotopic Data

Rb-Sr and Sm-Nd isotopic data of hy-granitoids (charnockites) of Aimores Complex (details in Mello, 2000 unpubl.), performed at the CPGeo-USP, Brazil, with a mass spectometer VARIANMAT, model TH-5. The results are showed in Tables 1, 2 and Fig. 2. The granitoids of the Aimores Complex show $\varepsilon_{Sr(500\text{-}600Ma)}$ ranging from -5.9 to -8.07 and exhibited initial rates $^{87}Sr/^{86}Sr$ = 0.705-0.708. Sm-Nd data exhibited ε_{Nd} initial values strongly negative, suggesting crustal contribution in the source. The granitoids of the have $\varepsilon Nd_{(0)}$ values ranging from –12.95 to –10.94, and TDM model ages ranging from 1,513.6 to 2,023.7 Ga, suggesting a Meso to Paleoproterozoic sources.

Table 1 - Rb/Sr Results of Aimores Pluton whole rock isotopic analyses.

Sample	Unit	Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}Sr$	Error	$^{87}Sr/^{86}Sr$	Error
S4	SCh	142.4	339.6	1.215	0.034	0.71756	0.00009
S25	SCp	124.9	332.8	1.087	0.031	0.71686	0.00009
S1	SGG	146.6	75.6	5.644	0.159	0.76548	0.00007
S21	SMGp	71.2	215.5	0.957	0.027	0.71962	0.00009

Table 2- Sm/Nd data from Aimores Pluton.

Sample	Sm(ppm)	Nd(ppm)	Sm/Nd	$^{147}Sm/^{144}Nd$	Erro	$^{143}Nd/^{144}Nd$	Error	TDM(Ma.)	Factr f	εNd0	εNd500.	εNd600Ma.
S4	12.456	70.273	0.177251	0.1072	0.0004	0.511984	0.00004 1	1513.6 ± 54.8	-0.455	-12.76	-7.05	-5.90
S25	16.551	77.978	0.212252	0.1283	0.0004	0.512077	0.00004	1721.9 ± 65.8	-0.347	-10.94	-6.58	-5.71
S1	7.425	32.659	0.227349	0.1375	0.0005	0.512031	0.00004 5	2023.7 ± 82.1	-0.301	-11.84	-8.07	-7.31
S21	7.936	41.555	0.190975	0.1155	0.0004	0.511974	0.00003	1656.6 ± 43.5	-0.412	-12.95	-7.77	-6.74

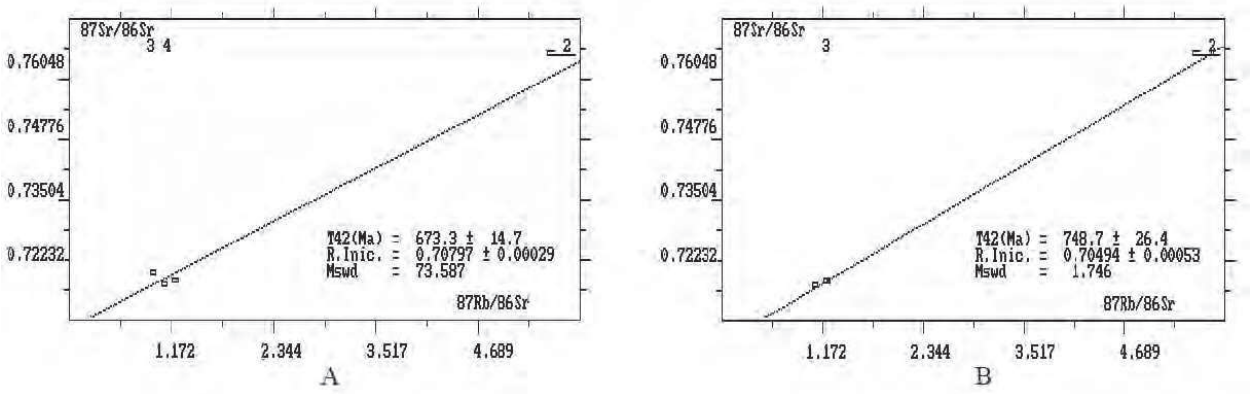

Fig. 2. Rb-Sr Isochron diagram from Aimores granitoids (A) and only for charnockites (B)

The U-Pb-Th monazite ages of two Aimores Complex charnockite samples were calculated from 31 analyses in U, Pb and Th monazite concentrations obtained by electron microprobe on thin sections. The U-Pb-Th determinations on monazites were performed on a Cameca SX100 electron microprobe at the Laboratoire Magmas et Volcans of the University of Blaise Pascal, Clermont-Ferrand (France). Analytical conditions included an accelerating voltage of 15 kV and a beam current of 150 nA. The theoretical basis and associated statistical treatment of data follow the analytical procedure detailed by Montel et al.(1996).

Monazites in hy-granitic rocks of the Aimores pluton yield average U-Th-Pb ages for the first sample of 470 ± 15 Ma; 502 ± 18 Ma and 552 ± 30 Ma, respectively 471 ± 24 Ma, 515 ± 24 Ma and 567 ± 50 Ma for the second one. The whole group taken together gives ages from 445 Ma to 572Ma.

U-Pb isotopic dilution analyses were carried out (Geochron Labs, United States) on separated zircon crystals from one charnockite sample. Fourteen elongated pale-rose zircons were grouped (Z2 in Fig. 3) and one single ablated crystal was analysed (Z1 in Fig. 3).

The zircon crystals are concordant, and indicate an emplacement age (lower intercept) of 498 ± 35.6 Ma.

The monazite and zircon crystals analyses could indicate an age ~500Ma for the charnockite emplacement, thus, maximum age for related pegmatites

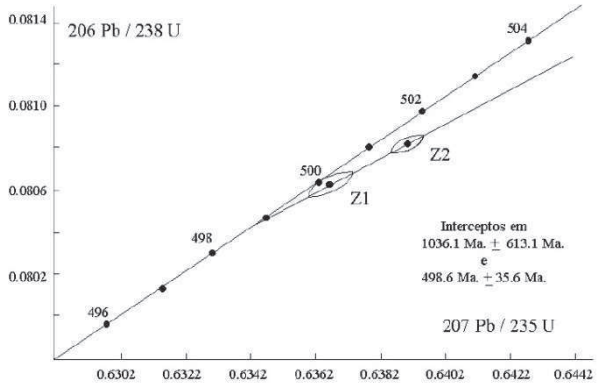

Fig. 3. Concordia diagram for hy-granitoids of Aimores Complex. Z1 represents one single zircon, Z2 a group of 14 zircons. Sample S10.

5. Conclusions

U-Pb isotopic charnockite zircon ages are the more precise. However, U-Pb-Th monazite ages obtained by electron microprobe provide similar ages and constrain these later pegmatites at about 500 Ma, which is in accordance with micas ages obtained by Viana et al. (2003).

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